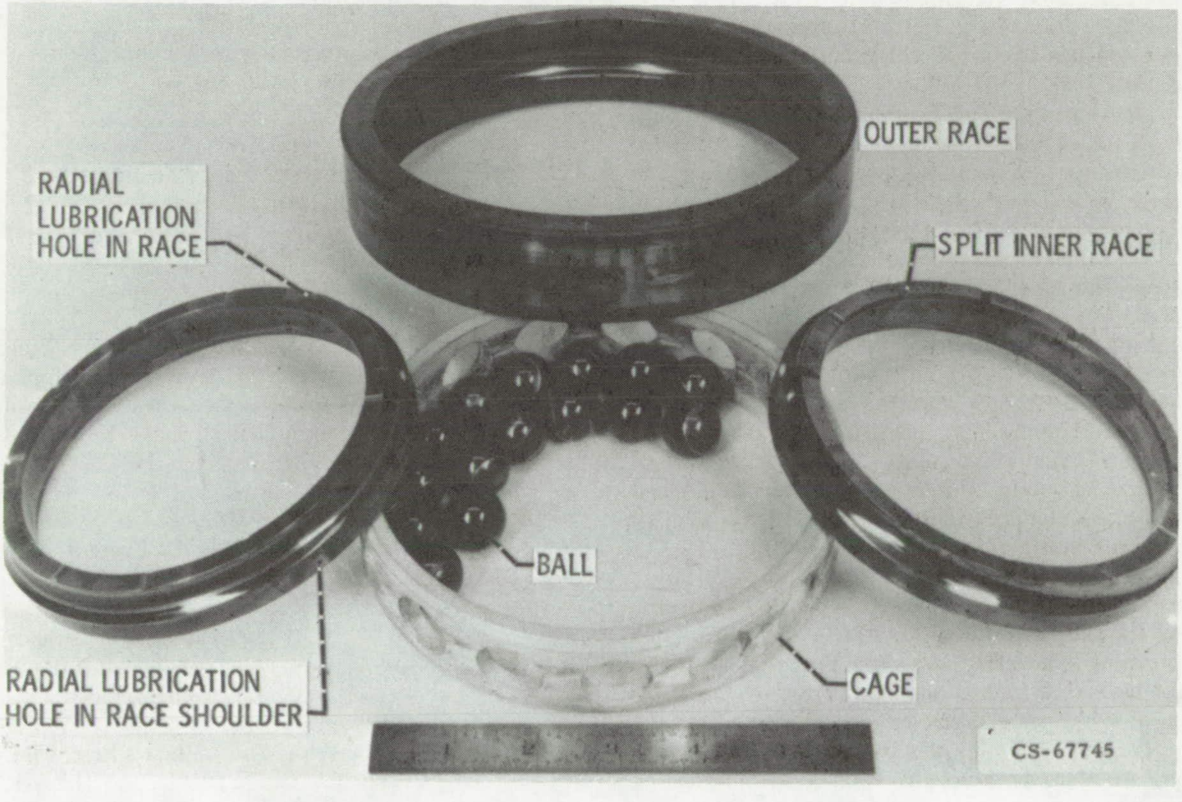
NASA TECH BRIEF

Lewis Research Center

Long Life, High Speed, Thrust-Load Ball Bearings



The Problem:

Advanced air breathing engines for future high-speed aircraft are expected to operate with bearing temperatures near 492 K (425°F) and at speeds approaching three million DN. (DN is a bearing speed parameter equal to the bearing bore in millimeters multiplied by the shaft speed in revolutions per minute.) For these engines and for similar high performance bearing applications, a reliable bearing and lubrication system is required. Such a system requires essentially three key items: a suitable lubricant, a reliable bearing structural material, and an optimized bearing design coupled with the proper operational parameters needed to sustain ultrahigh speeds.

Heat generation within the bearing itself is extremely critical, as is component loading due to centrifugal effects. At high speed, the effect of centrifugal loading of the rolling elements against the outer race of the bearing becomes extremely important. Theoretical life calculations for a conventional 150-mm bore angular-contact ball bearing operating at 20,000 rpm (three million DN) predict that this bearing has only about 20% of the AFBMA-predicted life (Anti-Friction Bearing Manufacturers' Association catalogue or predicted life) due to the increased stress in the outer race caused by centrifugal effects. Extremely short bearing life can be expected at speeds much above two million DN both in actual running time and in total bearing inner-race revolutions.

(continued overleaf)

The Solution:

Long-term bearing operation at three million DN can be achieved with a high degree of reliability using the full combination of sophisticated but currently available state-of-the-art bearing materials and designs, lubricants, and lubricating techniques.

How It's Done:

Over the past decade, several new classes of lubricants were developed and evaluated which extended the upper temperature range of lubricating fluids. Of these, tetra-ester fluids have proven to be most useful and applicable in typical air-breathing engine environments. These fluids have good thermal stability at temperatures to 505 K (450°F). Conventional bearing life at 492 K (425°F) using tetra-ester lubricants exceeded AFBMA-predicted (catalogue) life by more than four times.

Previous research indicated that AISI M-50 steel produced the most favorable life results at elevated temperatures when compared with other high-temperature bearing steels.

Split inner-race 120-mm bore ball bearings were built to ABEC-5 grade (Annular Bearings Engineers Committee) specifications for precision ball bearings. The inner and outer races, as well as the balls, were manufactured from one heat of double vacuum-melted (vacuum-induction melted, consumable-electrode vacuum remelted) AISI M-50 steel. The inner and outer-race curvatures were 54 and 52 percent, respectively. All components with the exception of the cage were heat treated to a Rockwell C hardness of 63 and were matched within ± one Rockwell-C point. This matching assured a nominal differential hardness in all bearings (i.e., the ball hardness minus the race hardness, commonly called ΔH) of zero. Surface finish of the balls was 2.5 μcm (one microinch) AA and the inner and outer raceways were held to a 5 μcm (2 microinch) AA maximum surface finish.

As shown in the photograph, under-race lubrication was provided by means of radial slots machined into the halves of the split inner races, the most reliable technique for lubricating high-speed bearings. Provision was also made for inner-race land-to-cage lubrication by the incorporation of several small diameter holes radiating from the bore of the inner race to the center of the inner race shoulder. As a result, both the cooling and lubricating functions were accomplished using a tetra-ester fluid.

Endurance tests were run for a total time of more than 60,000 hours at three million DN and a temperature of 492 K (425°F) with bearings having a nominal 24° contact angle at a thrust load of 22240 N (5000 lb). Bearing life exceeded 100 times AFBMA predicted life.

Notes:

1. Bearing operating temperature, temperature differences between the inner and outer races, and bearing power consumption can be tuned to any desirable operating requirement by varying four parameters: outer-race cooling, inner-race cooling, lubricant flow to the inner race, and oil inlet temperature.
2. Further information is available in the following reports:

   NASA TM-X-68264 (N73-26479), Parametric Study of the Lubrication of Thrust Loaded 120-MM Bore Ball Bearings to 3 Million DN

   NASA TN-D-7837 (N75-12330), Operating Characteristics of 120-Millimeter-Bore Ball Bearings at $3X10^6$ DN

   Copies may be obtained at cost from:

   Aerospace Research Applications Center
   Indiana University
   400 East Seventh Street
   Bloomington, Indiana 47401
   Telephone: 812-337-7833
   Reference: B75-10022
3. Specific technical questions may be directed to:

   Technology Utilization Officer
   Lewis Research Center
   21000 Brookpark Road
   Cleveland, Ohio 44135
   Reference: B75-10022
4. A movie, "The 3 Million DN Bearing Program," describes in more detail this bearing technology and is available for a no-cost, two-week loan from the Technology Utilization Officer, Lewis Research Center (address above).

Patent Status:

NASA has decided not to apply for a patent.

Source: H. Signer
Industrial Tectonics, Inc.,
E.N. Bamberger
General Electric Co., and
E.V. Zaretsky
Lewis Research Center
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